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The efforts on this contract were directed toward further development of the theory of periodically correlated (cyclostationary) and almost periodically correlated processes and to further investigation of the exploitation of harmonic signal structure in battlefield acoustical data. In addition a major part of the effort was devoted to problems in target positioning and tracking based on acoustical data.

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Final Report on Contract DAAD19-00-C-0124

February 2, 2002

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1 Introduction

The purpose of this report is to document the work conducted on contract DAAD19-00-C-0124 in the period 25 September 2000 through 31 December 2001.

The efforts on this contract were directed toward further development of the theory of periodically correlated (cyclostationary) and almost periodically correlated processes and to further investigation of the exploitation of harmonic signal structure in battlefield acoustical data. In addition a major part of our effort was devoted to problems in target positioning and tracking based on acoustical data.

2 Summary of Results

The major areas of work are summarized in the following paragraphs.

The Wold Isomorphism for Cyclostationary Sequences This work (see [2] for the original version) was revised to make a connection to the idea that PC sequences are harmonizable and therefore are projections of a stationary sequence. In the case of non-random cyclostationary sequences, such a stationary sequence exists naturally by viewing the non-random cyclostationary as element of a different Hilbert space. The manuscript has been submitted to *Signal Processing*.

Correlation and Spectral Theory for Periodically Correlated Fields Indexed on $\mathbf{Z}^2$ This manuscript, (see [3] for the original version) was revised to remove the more obvious proofs and to make a connection to problems related to systems having periodically varying parameters (with respect to time or space). The manuscript has been submitted to *Journal of Multivariate Analysis*.

On AR(1) Models with Periodic and Almost Periodic Coefficients This manuscript (see [8] for the original version) was revised and has been accepted for publication by *Stochastic Processes and Their Application*.

Spectral estimation for a strongly periodically correlated random field defined on Z^2 This manuscript (see [1] for the original version) has been reviewed by *Mathematical Methods of Statistics*. Revisions are being made to meet the meet the suggestions objections of the reviewer.

Harmonic Coherence Previous work on *harmonic coherence* [4] demonstrated methods for detecting the presence of harmonic coherence and that harmonic signals occurring battlefield acoustics sometimes have significant coherence.

During the work on this contract, the primary conclusion related to harmonic coherence was that signal processing parameters based on harmonic structure need to be incorporated into target association, positioning and tracking. Hence effort was begun on target positioning and tracking problems. See the next topic.

Target Positioning and Tracking This work was motivated by (1) the idea that parameters (such as doppler and time delay) derived from harmonic signal processing can help solve tracking in the multi-target environment (2) several papers at the 2000 Battlefield Acoustics Symposium from which we perceived a general need for improvement of positioning and tracking.

The work in the past year has demonstrated that a batch tracking algorithm can decrease the mean miss distance relative to the usual sequential localizer by at least a factor of two[9, 10]. In a preliminary analysis of bearing errors [11], the presence of bearing dependent biases were found, emphasizing the need for further study of bearing error mechanisms.

PARMA Models with Unit Roots This effort explored the meaning of periodic ARMA sequences having unit roots. The findings were presented at the IFAC International Workshop on Periodic Control, 27,28 August, 2001. The results will be turned into a manuscript and also included in the book manuscript.

Book manuscript: "Periodically Correlated Random Sequences, Spectral Theory and Practice" Considerable effort has been devoted to this book manuscript. It is scheduled for completion in 2002.

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